Distribution Switchgear Philosophies - Deadfront vs. Livefront

- Jared Newton
  Connexus Energy
  Distribution Engineering & Planning

- Michael Renman
  Xcel Energy
  Electric Distribution Standards

- Neil Stiller
  Rochester Public Utilities
  Maintenance & Construction
PANEL – DISTRIBUTION SWITCHGEAR PHILOSOPHIES: DEAD-FRONT VS. LIVE FRONT

Minnesota Power Systems Conference – November 4, 2020
Jared Newton, P.E.
ABOUT CONNEXUS ENERGY

136,000+ members
1,000 square miles territory
44 substations
12.5 kV 9,000 miles of line
3,000 miles overhead
6,000 miles underground
91% residential by customer
System peak demand 550 MW
SWITCHGEAR AT CONNEXUS ENERGY

• Today we have ~450 switchgear
  • 3 phase systems....
  • 449 livefront, 1 deadfront
  • Mostly 600 Amp rated switches
  • Mostly S&C
  • Oldest on the system from the late ‘70s
WHY ARE WE MOVING TO DEADFRONT SWITCHGEAR

Reliability

- Animal and vegetation outages
- 3 year history
  - 7 mouse outages (6 momentary)
  - 1 vegetation outage
- Reclosing on fully underground circuits
WHY ARE WE MOVING TO DEADFRONT SWITCHGEAR
WHY ARE WE MOVING TO DEADFRONT SWITCHGEAR
WHY ARE WE MOVING TO DEADFRONT SWITCHGEAR

your most powerful membership™
WHY ARE WE MOVING TO DEADFRONT SWITCHGEAR

your most powerful membership™
WHY ARE WE MOVING TO DEADFRONT SWITCHGEAR

your most powerful membership™
CONCERNS ABOUT MAKING THE CHANGE

• Processes and procedures including safety rules
  • Safety rules
  • Operating procedures
  • New elbows

• How to replace damaged gear
  • Is there enough cable for the elbow to reach
  • Doesn’t fit on the same basement
PATH FORWARD

- Starting in 2021 all new switchgear will be deadfront
- No plan to buy new livefront switchgear
  - Refurbish a few as they come in from the field for spares
- Damaged switchgear to be replaced with deadfront switchgear
- Eventually develop a program to proactively replace livefront switchgear with deadfront.
Switchgear Philosophies Live-Front vs Dead-Front

MIPSYCON November 2020
Michael Renman
Electric Distribution Standards
Fully Regulated and Vertically Integrated

Four Operating Companies
Eight States
3.6 Million Electric Customers
2.0 Million Natural Gas Customers
$30 Billion 2019 Est. Rate Base
19 GW Owned Gen. Capacity
11,000+ Employees

As of 10/31/2019

Northern States Power Minnesota (NSPM)
Minnesota, South Dakota, North Dakota
• 2019E Rate Base: $11.2 billion
• 2018 Ongoing EPS: $0.96
• 2020-2024 Cap Ex: $8.9 billion

Northern States Power Wisconsin (NSPW)
Wisconsin, Michigan
• 2019E Rate Base: $1.7 billion
• 2018 Ongoing EPS: $0.19
• 2020-2024 Cap Ex: $1.7 billion

Public Service Company of Colorado (PSCo)
Colorado
• 2019E Rate Base: $12.4 billion
• 2018 Ongoing EPS: $1.08
• 2020-2024 Cap Ex: $7.7 billion

Southwestern Public Service (SPS)
Texas, New Mexico
• 2019E Rate Base: $4.9 billion
• 2018 Ongoing EPS: $0.42
• 2020-2024 Cap Ex: $3.8 billion
Xcel Energy Distribution System Stats

• 47,408 Overhead Distribution Circuit Miles
  – MN, ND, SD 14,954 Miles
• 28,703 Underground Distribution Circuit Miles
  – MN, ND, SD 11,706 Miles
• 2,937 Feeders
• Padmount Switchgear
  – 15kV & 25kV Mostly live-front S&C
  – 35kV Deadfront Mostly Cooper/Eaton VFI
Wildlife Outages

• Average 7 animal related outages per year in our Minnesota service area
• Average 17 animal related outages per year in our Colorado service area
Xcel Energy discontinued the field practice of fault finding with fuses in 2014 and has experienced a major reduction in faults during switching.
System Constraints

- Existing system has many installations with feeder cables double-lugged
- 650 amp rated gear where extra capacity is required.
- Many areas with limited experience terminating 600 amp elbows
- Often limited cable slack available
35kV Deadfront Fault Example
New 35kV Source Transfer Gear
Distribution Switchgear Philosophies Deadfront vs. Livefront

Rochester Public Utilities
Padmounted Switchgear History and Present Applications

2020 MIPSYCON
Rochester Public Utilities (RPU)

• Minnesota’s largest municipal utility
  – 826 miles of 13.8 kV distribution system
  – 524 miles of underground primary (63%)
  – 66 sq. miles of municipal service territory
  – 56,400 electric customers

• 69 padmounted units and 9 submersible units in service

• 1 - 4 installed per year
History of Switchgear Use

Prior to 1996 RPU exclusively used Cooper RVAC and MOST oil-filled dead-front switches.

&

Trayer oil-filled switches installed in below-grade vaults.

Both designs used the same fuses
History of Switchgear Use

Combined Technologies
SX Limiter or Cooper
ELSP fuse

• Mostly used the 200 amp single barrel
• Current-limiting element in series with an expulsion element

Expulsion element operation contaminates the oil – overtime this requires oil filtration or refill.
History of Switchgear Use

Principle Disadvantages of Oil-filled switches

- Expensive switch and concrete foundation
- Costly fuses
- Oil maintenance – filtration / refill
- Fuse TCC curve choice was limited
- Absence of visible open switch contacts *
- Leaking oil in aged units
- Internal switch faults were catastrophic due to arc under oil producing dangerous gases. *
Arc Under Oil Damage

- Cooper RVAC
- 5 kA arc fault, one reclose

- Initial fault was at the cable terminators
- Tremendous fault forces caused massive internal damage and internal fault
- Tank ruptured and approx. 300 gallons oil spilled
Arc Under Oil Damage

- Cooper RVAC
- 5 kA arc fault, one reclose

- Initial fault was at the cable terminators
- Tremendous fault forces caused massive internal damage and internal fault
- Tank ruptured and approx. 300 gallons oil spilled
Arc Under Oil Damage

- Cooper RVAC
- 5 kA arc fault, one reclose

- Initial fault was at the cable terminators
- Tremendous fault forces caused massive internal damage and internal fault
- Tank ruptured and approx. 300 gallons oil spilled
Arc Under Oil Damage

- Cooper RVAC
- 5 kA arc fault, one reclose

- Initial fault was at the cable terminators
- Tremendous fault forces caused massive internal damage and internal fault
- Tank ruptured and approx. 300 gallons oil spilled
Arc Under Oil Damage

- Cooper RVAC
- 5 kA arc fault, one reclose

- Initial fault was at the cable terminators
- Tremendous fault forces caused massive internal damage and internal fault
- Tank ruptured and approx. 300 gallons oil spilled
History of Switchgear Use

Proponents for Change

- Readily viewable visible open switches
- Some improvement in fuse TCC curve choices
- Less expensive overall switch installation
- No oil to maintain or leak
- Avoid SF$_6$ regulatory issues
- Easier and cheaper cable termination
Switchgear Choices
mid 2000’s

Air Insulated Live-Front

- RPU linemen had a strong distaste for live-front transformers, but initially were accepting of live-front switches because of the shortcomings of the older existing units.
- Live-front switches developed a negative history due to rodent ingress and tight component clearances.
- Rigging to pull cable into some padmount switch designs identified other issues.
Adverse Experiences

Air Insulated Live-Front

• Some failures due to animals burrowing into the basement and then climbing upwards into the energized parts.

• New MNDOT road salts are applied as liquid – these corrosive materials seem to be more airborne and migrate easily throughout the cabinet spaces.
Present Design Change Approach

RPU evaluated three dead-front switch types
– Focused on field constructability and reliability features
  • Preference for fuses vs. electronic tripping
  • Shutters and internal fuse mount features
  • Cable pull-in access
  • Solid-dielectric components when available, but these have premium costs
Present Design Change Approach

- Shutters and internal fuse mount features
- Component or Switch viewing windows
Other Application Issues

– Air-insulated and dead-front equipment require a 15% - 20% larger footprint.
  • Difficult in city center areas due to very congested real estate.
  • Size mismatch complicates replacement when old equipment used concrete foundations.

– Perceived safety
  • Pulling cable into a de-energized switch bay
  • Access while inserting and removing fuses
Other Application Issues

– City core real estate issues may require a solid-dielectric compact design

– Suburban areas allow some space flexibility, so a second solution is allowed.